



Europäisches Patentamt
European Patent Office
Office européen des brevets



⑪ Publication number:

0 430 241 A1

⑫

EUROPEAN PATENT APPLICATION

⑬ Application number: 90122855.1

⑮ Int. Cl.⁵: B32B 15/01, C22C 37/06

⑭ Date of filing: 29.11.90

⑯ Priority: 30.11.89 JP 311419/89

⑰ Applicant: HITACHI METALS, LTD.

⑰ Date of publication of application:
05.06.91 Bulletin 91/23

1-2, Marunouchi 2-chome
Chiyoda-ku, Tokyo 100(JP)

⑱ Designated Contracting States:
DE FR Bulletin 00/6

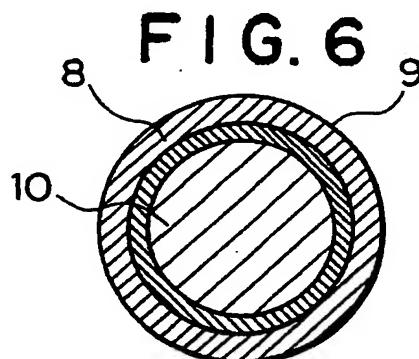
⑲ Inventor: Hattori, Toshiyuki
B-402, 11-54, Nakahata-machi, Wakamatsu-ku
Kitakyushu-shi, Fukuoka-ken(JP)
Inventor: Ooshima, Masahiko
B-302, 11-54, Nakahata-machi, Wakamatsu-ku
Kitakyushu-shi, Fukuoka-ken(JP)
Inventor: Nawata, Ryosaku
1-14, Miyamae-machi, Wakamatsu-ku
Kitakyushu-shi, Fukuoka-ken(JP)

⑳ Representative: Patentanwälte Beetz sen. -
Beetz jun. Timpe - Siegfried -
Schmitt-Fumian- Mayr
Steinsdorfstrasse 10
W-8000 München 22(DE)

㉑ Wear-resistant compound roll.

㉒ There is provided according to the present invention a wear-resistant compound roll comprising an outer layer (8) and a shaft portion (10) produced by a centrifugal casting method. The outer layer (8) and the shaft portion (10) are metallurgically bonded to each other, and the outer layer (8) is made of an iron-base alloy having a composition (by weight %) consisting essentially of 1-4 % of C, 3 % or less of Si, 1.5 % or less of Mn, 4 % or less of Ni, 2-15 % of Cr, 8 % or less of Mo, 20 % or less of W, 2-10 % of V and balance substantially Fe and inevitable impurities, the value of C (%) + 0.4 V (%) being 6.0 or less. This compound roll has excellent wear resistance without casting defects in the boundary between the outer layer (8) and the shaft portion (10).

EP 0 430 241 A1



WEAR-RESISTANT COMPOUND ROLL

BACKGROUND OF THE INVENTION

The present invention relates to a wear-resistant compound roll for hot or cold rolling.

Widely used as rolls for hot or cold rolling are compound rolls produced by a centrifugal casting method. To show wear resistance and toughness simultaneously, these compound rolls have a structure consisting of an outer layer made of wear-resistant materials and a shaft portion made of gray cast iron or ductile cast iron having large toughness. These compound rolls can be produced by pouring a melt for an outer layer into a centrifugal casting mold rotating at a high speed, thereby forming a hollow outer layer, and then pouring a melt for a shaft portion into the hollow outer layer in the casting mold, thereby metallurgically bonding the shaft portion to the outer layer. In this case, part of an inner portion of the outer layer is remelted by the heat of the melt for the shaft portion, and then resolidified.

In such centrifugally cast compound rolls, the outer layers advantageously contain hard carbides for higher wear resistance. As materials for the outer layers of such rolls, high-chromium cast iron containing a large amount of hard Cr carbides as disclosed by "Iron and Steel Engineer," April 1979, pp.42-49 are widely used.

In order to obtain higher wear resistance than that of the high-chromium cast iron, it may be considered to add a large amount of V, W, Mo, etc. for forming harder carbides than the Cr carbides. However, compound rolls cannot be produced from these materials by a centrifugal casting method for the reasons below.

With respect to V, it forms hard VC carbides extremely important for improving wear resistance, but the VC carbides have relatively small specific gravities, showing a large difference in specific gravity between the melt and the VC carbides. Accordingly, in the process of centrifugal casting, the VC carbides tend to be concentrated on the inner side of the outer layer. This leads to extremely reduced amounts of C and V on the roll surface.

V, W, Mo, etc. forming hard carbides are elements having a tendency of producing white cast iron, and they tend to be dissolved in the cast iron or steel of the shaft portion at the time of bonding the outer layer and the shaft portion. As a result, in a case where the shaft portion is made of cast iron, its graphitization is extremely deteriorated. Thus, the shaft portion becomes brittle, causing breakage in the process of producing the roll or during the rolling operation.

Further, in a case where the shaft portion is made of steel, in which graphite and carbides are not precipitated, the addition of such elements of producing white cast iron does not cause the brittleness of the shaft portion, but the shaft portion has a higher melting point than the outer layer, so that the outer layer is melted when a melt for the shaft portion is poured, producing a finally solidified layer at the boundary between the outer layer and the shaft portion, which is a mixture of the outer layer alloy and the shaft portion alloy. This boundary portion is likely to have casting defects such as voids.

OBJECT AND SUMMARY OF THE INVENTION

In view of the above problems, an object of the present invention is to provide a wear-resistant compound roll composed of an outer layer made of a cast iron in which hard carbides of V, Mo, W, etc. are uniformly distributed, and a shaft portion made of cast iron or steel, in which graphite particles are well precipitated, the outer layer and the shaft portion being metallurgically bonded to each other.

In the production of a compound roll containing hard carbides such as VC by a centrifugal casting method, the first problem is the centrifugal separation of VC carbides from the melt due to their difference in specific gravity. As a result of investigation to solve this problem, the segregation of the VC carbides caused by the centrifugal separation can be reduced when the melt has a composition which causes little precipitation of the VC carbides in a primary crystal. Specifically, by providing the melt with a composition of having a composition (by weight %) consisting essentially of 1-4% of C, 3% or less of Si, 1.5% or less of Mn, 4% or less of Ni, 2-15% of Cr, 8% or less of Mo, 20% or less of W, 2-10% of V and balance substantially Fe and inevitable impurities, the value of C [%] + 0.4 V [%] being 8.0 or less, the precipitation of VC carbides in the primary crystal can be substantially suppressed, decreasing the segregation of the VC carbides in a portion near the inner surface of the outer layer. Thus, the outer layer having good wear resistance can be obtained by a centrifugal casting method. The present invention has been made based upon this finding.

Thus, the wear-resistant compound roll according to the present invention comprises an outer layer and

5 a shaft portion produced by a centrifugal casting method, the outer layer and the shaft portion being metallurgically bonded to each other, the outer layer being made of an iron-base alloy having a composition (by weight %) consisting essentially of 1-4% of C, 3% or less of Si, 1.5% or less of Mn, 4% or less of Ni, 2-15% of Cr, 8% or less of Mo, 20% or less of W, 2-10% of V and balance substantially Fe and inevitable impurities, the value of C (%) + 0.4 V (%) being 6.0 or less.

BRIEF DESCRIPTION OF THE DRAWINGS

10 Fig. 1 (1) is a photomicrograph showing the metal structure of the outer layer of the wear-resistant compound roll in Example 3;

Fig. 1 (2) is a photomicrograph showing the metal structure of the shaft portion of the wear-resistant compound roll in Example 3;

15 Fig. 2 is a graph showing the V distribution in a sleeve roll produced according to the present invention and that in a sleeve roll made of the conventional alloy material;

Fig. 3 is a graph showing wear profiles of rolls of the present invention and Comparative Example detected by the roll wear test apparatus;

20 Fig. 4 is a photomicrograph showing the metal structure of the shaft portion of the wear-resistant compound roll in Example 5;

Fig. 5 is a schematic view showing a rolling wear test apparatus for conducting a wear test; and

Fig. 6 is a schematic cross-sectional view showing the compound roll in Example 5.

DETAILED DESCRIPTION OF THE INVENTION

25 In the wear-resistant compound roll according to the present invention, the reasons for limiting the amounts (weight %) of components are as follows:

(a) C: 1-4 %

20 C is an indispensable element for forming carbides to increase the wear resistance of the roll. If it is less than 1%, the amount of carbides precipitated is insufficient, resulting in insufficient wear resistance. On the other hand, when C exceeds 4%, the amount of VC carbides precipitated in a primary crystal is excessive, resulting in the alloy structure in which VC carbides are extremely segregated. The preferred amount of C is 1-3%.

(b) Si: 3% or less

Si is a necessary element as a deoxidizer. When it exceeds 3%, the resulting cast iron becomes too brittle. The preferred amount of Si is 0.2-2%.

35 (c) Mn: 1.5% or less

Mn has a function of deoxidization and of trapping S, which is an impurity, as MnS. However, when it exceeds 1.5%, the alloy becomes brittle. The preferred amount of Mn is 0.2-1%.

(d) Ni: 4% or less

40 Ni has a function to improve the hardenability of the alloy by stabilizing an austenite phase. Accordingly, it is effective particularly when a large compound roll is produced. It can be added in an amount up to 4%. However, when exceeding this amount, the retained austenite cannot be easily decomposed, resulting in insufficient hardness and wear resistance. The preferred amount of Ni is 1.5% or less.

(e) Cr: 2-15%

45 Cr serves to increase the hardenability of the alloy and generate hard M₇C₃ carbides. When it is less than 2%, the hardenability of the alloy becomes insufficient, and when it exceeds 15%, the amount of hard VC carbides becomes too small. The preferred amount of Cr is 3-12%.

(f) Mo: 8% or less

50 Mo is necessary for obtaining good hardenability and tempering hardness, but when it exceeds 8%, the amount of M₂C or M₆C carbides increases, thereby undesirably decreasing the amount of harder VC carbides. The preferred amount of Mo is 0.5-6%.

(g) W: 20% or less

55 W has a function of improving tempering hardness, and it is dissolved in VC carbides to increase their specific gravity, thereby decreasing their gravity segregation. However, when it exceeds 20%, the amount of W₆C carbides increases, undesirably decreasing the amount of harder VC carbides. The preferred amount of W is 0.5-10%.

(h) V: 2-10%

V is an indispensable element for forming hard carbides which are effective for increasing wear

resistance. When it is less than 2%, sufficient effects cannot be obtained, and when it exceeds 10%, granular VC carbides are excessively precipitated in a primary crystal, so that the VC carbides having a relatively small specific gravity tend to be segregated in a portion near the inner surface of the outer layer. Accordingly, amount of V should be limited to 10% or less. The preferred amount of V is 3-8%.

5 The amount of V is mainly restricted by the amount of C. The inventors have found through various experiments a composition range in which the VC carbides are less precipitated in the primary crystal, causing the segregation of the VC carbides in the centrifugal casting process. Specifically, when C (%) + 0.4 V (%), by weight, is 6.0 or less, the precipitation of the VC carbides in the primary crystal is sufficiently small. Accordingly, with this composition range, the outer layer produced by a centrifugal
10 casting method suffers from little segregation of V and C into a portion near the inner surface of the outer layer, thereby providing the outer layer with a sufficiently uniform composition. The preferred range of C (%) + 0.4V (%) is 2-5.

(i) Other additive elements

15 In addition to the above elements, the iron-base alloy for the outer layer according to the present invention may further contain Ti, Zr or Nb alone or in combination. Ti, Zr and Nb are, like V, elements for forming hard carbides. By introducing these elements into the outer layer of the roll, the wear resistance of the roll can be increased. The amount of one or more elements selected from Ti, Zr and Nb is 5% or less in total. When the total amount of these elements exceeds 5% the amount of VC carbides becomes too small.

20 In the present invention, Co may be added to the outer layer. Co is dissolved in the matrix of the outer layer, increasing the high-temperature strength of the roll. Accordingly, the addition of Co is effective to improve the wear resistance and resistance to surface roughening of the compound roll for hot rolling. This effect is sufficient when up to 15% of Co is added. However, even though the Co content exceeds 15%, further improvement of wear resistance and resistance to surface roughening cannot be obtained. Accordingly, the upper limit of the Co content is 15% from the economic point of view.

25 Beside the above elements, the iron-base alloy for the outer layer consists substantially of iron except for inevitable impurities. Major impurities are P and S, and it is desired that P is 0.1% or less and S is 0.08% or less for preventing the alloy from becoming brittle.

30 Used in combination with the outer layer of the above composition to produce the compound roll is a shaft portion made of gray cast iron, ductile cast iron, graphitic cast steel, etc., in which graphite is precipitated. In this case, the problem is that the shaft portion becomes brittle due to the fact that elements of producing white cast iron such as V, W, Mo, etc. are dissolved into the shaft portion at the time of bonding the shaft portion to the outer layer in the centrifugal casting process. The inventors have found that this problem can be solved by the following means.

35 First, by properly selecting the time interval from the casting of the outer layer to the casting of the shaft portion, the casting temperature of the shaft portion, the components of the shaft portion, treatment conditions of the melt, etc., the melting of the inner surface of the outer layer at the time of bonding the shaft portion to the outer layer can be suppressed, thereby sufficiently reducing the amounts of the white casting iron-producing elements dissolved into the shaft portion.

40 The above means should be conducted under strictly controlled conditions and it takes a lot of time to determine the conditions when the components and sizes are different, but the dissolving of the white cast iron-producing elements into the shaft portion can be reduced relatively easily by forming an intermediate layer made of cast steel containing 2.5 weight % or less of C after casting the outer layer and before pouring gray cast iron, ductile cast iron, graphitic cast steel, etc. for the shaft portion. The preferred composition (by weight) of the intermediate layer consists essentially of 1-2.5% or less of C, 3% or less of Si, 1.5% or less of Mn, 1% or less of Ni, 3% or less of Cr, 1.5% or less of Mo, 2.5% or less of W, 2% or less of V and balance substantially Fe and inevitable impurities.

45 Further, in the production of the compound roll consisting of the above outer layer and the above shaft portion, if the shaft portion is made of cast steel, there is no problem that the shaft portion becomes brittle. However, casting defects are likely to be generated in a boundary between the outer layer and the shaft portion. As a result of investigation on this problem, the casting defects in the boundary can be prevented even when the shaft portion is made of steel, by properly selecting the time interval between the casting of the outer layer and the casting of the shaft portion, the casting temperature of the shaft portion, the components of the shaft portion, treatment conditions of the melt, etc., and further the shape of the casting mold and the cooling of the casting mold.

55 The present invention will be explained in further detail by means of the following Examples.

Example 1

Each of melts for outer layers having the compositions shown in Table 1 was poured into a CO₂ sand mold having a diameter of 70 mm and a height of 80 mm to cast a small roll having an outer diameter of 60 mm, an inner diameter of 35 mm and a length of 40 mm for rolling wear test. This roll was subjected to a heat treatment comprising hardening from 1000-1100 °C and tempering at 500-550 °C to provide a test roll.

5 The surface hardness of each test roll was measured by a Shore hardness tester, and the results are shown in Table 2. Next, this test roll was subjected to a rolling wear test. A rolling wear test machine used is as shown in Fig. 5, comprising a rolling mill 1, an upper roll 2 and a lower roll 3 in the rolling mill 1, a heating furnace 4 for preheating a sheet S to be rolled, a cooling water bath 5 for cooling the rolled sheet S, a reel 6 for winding the roll S while giving a constant tension to the sheet S during rolling operation, and a tension controller 7 for adjusting the tension. The test conditions were as follows:

Sheet S to be rolled: SUS 304, 1 mm thick and 15 mm wide

Rolling distance: 800 m

Rolling temperature: 900 °C

Rolling reduction: 25%

15 Rolling speed: 150 m/minute

Roll cooling: Water cooling

Wear depth on the surface of the test roll was measured by a needle contact-type surface roughness tester (SURFCOM). The results are shown in Fig. 3 (A) for sample No. 1. And for each roll the wear depth was averaged in a rolling width to obtain an average wear depth. The results are shown in Table 2.

20

Comparative Examples 1, 2

Example 1 was repeated to produce a test roll by using, as conventional materials, high-chromium cast iron (Comparative Example 1) and grain roll alloy material (Comparative Example 2). However, it should be noted that with respect to the heat treatment, appropriate conditions were selected for these materials. As in Example 1, a wear test was conducted and the measured values of wear depth are shown in Figs. 3 (B) (Comparative Example 1) and (C) (Comparative Example 2). And the measured hardness is also shown in Table 2.

30

35

40

45

50

55

5

10

15

20

25

30

35

40

45

50

55

60

65

70

75

80

85

90

95

100

105

110

115

120

125

130

135

140

145

150

155

160

165

170

175

180

185

190

195

200

205

210

215

220

225

230

235

240

245

250

255

260

265

270

275

280

285

290

295

300

305

310

315

320

325

330

335

340

345

350

355

360

365

370

375

380

385

390

395

400

405

410

415

420

425

430

435

440

445

450

455

460

465

470

475

480

485

490

495

500

505

510

515

520

525

530

535

540

545

550

555

560

565

570

575

580

585

590

595

600

605

610

615

620

625

630

635

640

645

650

655

660

665

670

675

680

685

690

695

700

705

710

715

720

725

730

735

740

745

750

755

760

765

770

775

780

785

790

795

800

805

810

815

820

825

830

835

840

845

850

855

860

865

870

875

880

885

890

895

900

905

910

915

920

925

930

935

940

945

950

955

960

965

970

975

980

985

990

995

1000

1005

1010

1015

1020

1025

1030

1035

1040

1045

1050

1055

1060

1065

1070

1075

1080

1085

1090

1095

1100

1105

1110

1115

1120

1125

1130

1135

1140

1145

1150

1155

1160

1165

1170

1175

1180

1185

1190

1195

1200

1205

1210

1215

1220

1225

1230

1235

1240

1245

1250

1255

1260

1265

1270

1275

1280

1285

1290

1295

1300

1305

1310

1315

1320

1325

1330

1335

1340

1345

1350

1355

1360

1365

1370

1375

1380

1385

1390

1395

1400

1405

1410

1415

1420

1425

1430

1435

1440

1445

1450

1455

1460

1465

1470

1475

1480

1485

1490

1495

1500

1505

1510

1515

1520

1525

1530

1535

1540

1545

1550

1555

1560

1565

1570

1575

1580

1585

1590

1595

1600

1605

1610

1615

1620

1625

1630

1635

1640

1645

1650

1655

1660

1665

1670

1675

1680

1685

1690

1695

1700

1705

1710

1715

1720

1725

1730

1735

1740

1745

1750

1755

1760

1765

1770

1775

1780

1785

1790

1795

1800

1805

1810

1815

1820

1825

1830

1835

1840

1845

1850

1855

1860

1865

1870

1875

1880

1885

1890

1895

1900

1905

1910

1915

1920

1925

1930

1935

1940

1945

1950

1955

1960

1965

1970

1975

1980

1985

1990

1995

2000

2005

2010

2015

2020

2025

2030

2035

2040

2045

2050

2055

2060

2065

2070

2075

2080

2085

2090

2095

2100

2105

2110

2115

2120

2125

2130

2135

2140

2145

2150

2155

2160

2165

2170

2175

2180

2185

2190

2195

2200

2205

2210

2215

2220

2225

2230

2235

2240

2245

2250

2255

2260

2265

2270

2275

2280

2285

2290

2295

2300

2305

2310

2315

2320

2325

2330

2335

2340

2345

2350

2355

2360

2365

2370

2375

2380

2385

2390

2395

2400

2405

2410

2415

2420

2425

2430

2435

2440

2445

2450

2455

2460

2465

2470

2475

2480

2485

2490

2495

2500

2505

2510

2515

2520

2525

2530

2535

2540

2545

2550

2555

2560

2565

2570

2575

2580

2585

2590

2595

2600

2605

2610

2615

2620

2625

2630

2635

2640

2645

2650

2655

2660

2665

2670

2675

2680

2685

2690

2695

2700

2705

2710

2715

2720

2725

2730

2735

2740

2745

2750

2755

2760

2765

2770

2775

2780

2785

2790

2795

2800

2805

2810

2815

2820

2825

2830

2835

2840

2845

2850

2855

2860

2865

2870

2875

2880

2885

2890

2895

2900

2905

2910

2915

2920

2925

2930

2935

2940

2945

2950

2955

2960

2965

2970

2975

2980

2985

2990

2995

3000

3005

3010

3015

3020

3025

3030

3035

3040

3045

3050

3055

3060

3065

3070

3075

3080

3085

3090

3095

3100

3105

3110

3115

3120

3125

3130

3135

3140

3145

3150

3155

3160

3165

3170

3175

3180

3185

3190

3195

3200

3205

3210

3215

3220

3225

3230

3235

3240

3245

3250

3255

3260

3265

3270

3275

3280

3285

3290

3295

3300

3305

3310

3315

3320

3325

3330

3335

3340

3345

3350

3355

3360

3365

3370

3375

3380

3385

3390

3395

3400

3405

3410

3415

3420

3425

3430

3435

3440

3445

3450

3455

3460

3465

3470

3475

3480

3485

3490

3495

3500

3505

3510

3515

3520

3525

3530

3535

3540

3545

3550

3555

3560

3565

3570

3575

3580

3585

3590

3595

3600

3605

3610

3615

3620

3625

3630

3635

3640

3645

3650

3655

3660

3665

3670

3675

3680

3685

3690

3695

3700

3705

3710

3715

3720

3725

3730

3735

3740

3745

3750

3755

3760

3765

3770

3775

3780

3785

3790

3795

3800

3805

3810

3815

3820

3825

3830

3835

3840

3845

3850

3855

3860

3865

3870

3875

3880

3885

3890

3895

3900

3905

3910

3915

3920

3925

3930

3935

3940

3945

3950

3955

3960

3965

3970

3975

3980

3985

3990

3995

4000

4005

4010

4015

4020

4025

4030

4035

4040

4045

4050

4055

4060

4065

4070

4075

4080

4085

4090

4095

4100

4105

4110

4115

4120

4125

4130

4135

4140

4145

4150

4155

4160

4165

4170

4175

4180

4185

4190

4195

4200

4205

4210

4215

4220

4225

4230

4235

4240

4245

4250

4255

4260

4265

4270

4275

4280

4285

4290

4295

4300

4305

4310

4315

4320

4325

4330

4335

4340

4345

4350

4355

4360

4365

4370

4375

4380

4385

4390

4395

4400

4405

4410

4415

4420

4425

4430

4435

4440

4445

4450

4455

4460

4465

4470

4475

4480

4485

4490

4495

4500

4505

4510

4515

4520

4525

4530

4535

4540

4545

4550

4555

4560

4565

4570

4575

4580

4585

4590

4595

4600

4605

4610

4615

4620

4625

4630

4635

4640

4645

4650

4655

4660

4665

4670

4675

4680

4685

4690

4695

4700

4705

4710

4715

4720

4725

4730

4735

4740

4745

4750

4755

4760

4765

4770

4775

4780

4785

4790

4795

4800

4805

4810

4815

4820

4825

4830

4835

4840

4845

4850

4855

4860

4865

4870

4875

4880

4885

4890

4895

4900

4905

4910

4915

4920

4925

4930

4935

4940

4945

4950

4955

4960

4965

4970

4975

4980

4985

4990

4995

5000

5005

5010

5015

5020

5025

5030

5035

5040

5045

5050

5055

5060

5065

5070

5075

5080

5085

5090

5095

5100

5105

5110

5115

5120

5125

5130

5135

5140

5145

5150

5155

5160

5165

5170

5175

5180

5185

5190

5195

5200

5205

5210

5215

5220

5225

5230

5235

5240

5245

5250

5255

5260

5265

5270

5275

5280

5285

5290

5295

5300

5305

5310

5315

5320

5325

5330

5335

5340

5345

5350

5355

5360

5365

5370

5375

5380

5385

5390

5395

5400

5405

5410

5415

5420

5425

5430

5435

5440

5445

5450

5455

5460

5465

5470

5475

5480

5485

5490

5495

5500

5505

5510

5515

5520

5525

5530

5535

5540

5545

5550

5555

5560

5565

5570

5575

5580

5585

5590

5595

5600

5605

5610

5615

5620

5625

5630

5635

5640

5645

5650

5655

5660

5665

5670

5675

5680

5685

5690

5695

5700

5705

5710

5715

5720

5725

5730

5735

5740

5745

5750

5755

5760

5765

5770

5775

5780

5785

5790

5795

5800

5805

5810

5815

5820

5825

5830

5835

5840

5845

5850

5855

5860

5865

5870

5875

5880

5885

5890

5895

5900

5905

5910

5915

5920

5925

5930

5935

5940

5945

5950

5955

5960

5965

5970

5975

5980

5985

5990

5995

6000

6005

6010

6015

6020

6025

6030

6035

6040

6045

6050

6055

6060

6065

6070

6075

6080

6085

6090

6095

6100

6105

6110

6115

6120

6125

6130

6135

6140

6145

6150

6155

6160

6165

6170

6175

6180

6185

6190

6195

6200

6205

6210

6215

6220

6225

6230

6235

6240

6245

6250

6255

6260

6265

6270

6275

6280

6285

6290

6295

6300

6305

6310

6315

6320

6325

6330

6335

6340

6345

6350

6355

6360

6365

6370

6375

6380

6385

6390

6395

6400

6405

6410

641

Table 2

5	Sample ⁽¹⁾ No.	Hardness (HS)	Average Wear Depth (μm)
10	1	85	0.6
15	2	83	0.7
20	3	83	0.6
25	4	80	0.9
30	5	85	0.5
35	6	82	0.6
40	7	80	0.8
45	8	83	0.7
50	9	82	0.8
55	10	82	0.7
60	11	84	0.7
65	12	75	1.5
70	13	78	2.3

35 Note (1): Sample Nos. 1-11: Present invention.

Sample Nos. 12 and 13: Comparative

40 Examples 1 and 2.

45 Example 2

Each of melts ((a): present invention, (b): conventional material) for outer layers having the compositions shown in Table 3 was poured into a mold having a cavity diameter of 450 mm and a cavity length of 750 mm to cast a sleeve roll having a thickness of 60 mm. The rpm of the mold was set such that a centrifugal force on the inner surface of the sleeve roll was 140 G.

50

55

Table 3

Component (wt. %)	Present Invention (a)	Conventional Material (b)
C	2.05	2.67
Si	0.75	0.72
Mn	0.42	0.43
P	0.031	0.033
S	0.015	0.015
Ni	0.33	0.29
Cr	6.11	6.08
Mo	2.07	2.08
V	6.26	11.05
W	3.98	4.15

The distribution of V content from the outside to the inside of each as-cast sleeve roll, which is a measure of the VC content, is shown in Fig. 2.

In the sleeve roll made of the cast iron of the present invention (a), little segregation of VC carbides toward the inside of the sleeve roll was observed. On the other hand, the sleeve roll made of the conventional material (b) suffers from large segregation, meaning that the V content is extremely large at the inside of the sleeve roll.

Example 3

A compound roll composed of an outer layer and a shaft portion each having the composition shown in Table 4 and having a roll diameter of 450 mm and a roll length of 750 mm was produced by the following procedure.

40

45

50

55

Table 4

<u>Component (wt. %)</u>	<u>Outer Layer</u>	<u>Shaft Portion</u>
C	2.03	3.44
Si	0.78	2.55
Mn	0.42	0.32
P	0.028	0.030
S	0.015	0.012
Ni	0.21	1.35
Cr	6.03	0.10
Mo	2.12	0.02
V	6.25	-
W	4.24	-
Mg	-	0.048

First, a melt for the outer layer was dissolved in a high-frequency furnace, and 450 kg of the melt was poured into a rotating centrifugal casting mold at 1450 °C. At this time, a flux for preventing the oxidation of the inner surface of the outer layer was introduced simultaneously. 15 minutes after casting the outer layer, the casting mold was stopped and erected vertically, and ductile cast iron for the shaft portion was immediately poured at 1400 °C. After cooling to room temperature, the casting mold was disassembled, and the resulting compound roll was roughly worked. It was then hardened by leaving it to cool from 1000 °C, and then it was subjected to a tempering treatment 3 times at 550 °C. After the heat treatment, it was confirmed by ultrasonic testing and color check that the compound roll had no defects.

The metal structures of the outer layer and the shaft portion of the compound roll were investigated by electrophotomicrography. Their photomicrographs are shown in Figs. 1 (1) and (2).

Next, a tensile test was conducted on the shaft portion in the longitudinal center portion of the compound roll. Near the boundary between the outer layer and the shaft portion, the shaft portion had a tensile strength of 464 N/mm² (47.3 kg/mm²) and an elongation of 0.41 %, and in its center, it had a tensile strength of 432.6 N/mm² (44.1 kg/mm²) and an elongation of 0.36 %. These values are satisfactory for the practical purpose.

45 Example 4

The production of a compound roll having a roll diameter of 450 mm and a roll length of 500 mm and having a shaft portion made of steel will be shown below. The components of melts for an outer layer, and the shaft portion are shown in Table 5.

50

55

Table 5

5	<u>Component (wt. %)</u>	<u>Outer Layer</u>	<u>Shaft Portion</u>
10	C	2.15	0.51
15	Si	0.65	0.35
20	Mn	0.81	0.70
25	P	0.028	0.025
30	S	0.019	0.026
35	Ni	0.15	0.11
40	Cr	6.43	1.01
45	Mo	3.11	0.18
50	V	6.60	-
55	W	5.01	-

Casting Conditions

290 kg of a melt for the outer layer was poured at 1420 °C into a rotating centrifugal casting mold (first mold) inclined by 20°, and a flux for preventing the oxidation of an inner surface of the outer layer was introduced immediately. After the solidification of the outer layer, the rotation of the casting mold was stopped immediately, and the casting mold was erected and placed on a vertical casting mold (second mold) for casting a roll journal portion. Another mold (third mold) for casting a roll journal portion was placed on a top of the first mold, and a melt for a shaft portion at 1250 °C was poured into the assembled casting mold. Incidentally, the lower casting mold (second mold) had a thickness of 150 mm or more, and the upper casting mold (third mold) was a sand mold provided with a temperature-keeping layer, thereby conducting the directional solidification of the shaft portion from the lower portion to the upper portion.

The roll thus cast had small cracks in the neck portion of the upper journal, but these defects could be removed by usual cutting. After cutting the outer layer of this roll, ultrasonic testing was conducted. As a result, it was confirmed that there were no defects which may cause practical problems in the boundary between the outer layer and the shaft portion, and that the shaft portion was practically satisfactory even though it had small casting voids in its center portion.

Tensile test samples were machined from a longitudinal center portion of this roll to conduct a tensile test. As a result, the shaft portion near the boundary had a tensile strength of 488.5 N/mm² (49.8 kg/mm²) and an elongation of 0.43 %, and the shaft portion in the center had a tensile strength of 437.5 N/mm² (44.6 kg/mm²) and an elongation of 0.38 %. These values are practically satisfactory.

Example 5

The production of a compound roll having a three-layer structure as schematically shown in Fig. 6, which has a roll diameter of 450 mm and a roll length of 750 mm, will be shown below. In Fig. 6, 8 denotes an outer layer, 9 denotes an intermediate layer, and 10 denotes a shaft portion. Each layer of this roll has a composition shown in Table 6.

Table 6

	<u>Component (wt. %)</u>	<u>Outer Layer</u>	<u>Intermediate Layer</u>	<u>Shaft portion</u>
6	C	2.21	1.73	3.35
10	Si	0.62	1.00	2.55
15	Mn	0.83	0.81	0.40
20	P	0.031	0.033	0.041
25	S	0.021	0.022	0.006
	Ni	0.12	0.75	1.4
	Cr	6.51	0.08	0.11
	Mo	3.02	0.03	0.030
	V	6.51	-	-
	W	4.82	-	-
	Mg	-	-	0.050

4200 kg of a melt for the outer layer 8 was poured at 1420°C into a rotating centrifugal casting mold 30 (first mold) inclined by 20°, and a flux for preventing the oxidation of an inner surface of the outer layer 8 was introduced immediately. After the solidification of the outer layer 8, 150 kg of a melt for the intermediate layer 9 at 1480°C was poured. Immediately after the intermediate layer 9 was completely solidified, a melt for the shaft portion 10 at 1400°C was poured to fill the mold.

After disassembling the mold, the resulting compound roll was worked in its outer surface to conduct an 35 ultrasonic testing. No defects were observed in boundaries between the outer layer 8 and the intermediate layer 9 and between the intermediate layer 9 and the shaft portion 10, verifying that the resulting compound roll was satisfactory.

Fig. 4 is an electrophotomicrograph of the metal structure of the shaft portion 10. The shaft portion 10 had good graphitization, meaning the desired metal structure.

40 According to the present invention, the compound roll having a wear resistance two to five times as high as that of the conventionally cast alloy rolls can be produced. Such high wear resistance leads to the increase of the service life of the compound roll, the reduction of roll exchange frequency, the improvement of the shapes of rolled articles, and the increase in flexibility of rolling schedule, etc.

On the other hand; although there is proposed a powder metallurgy method for producing high-wear 45 resistance rolls, such a method needs an extremely complicated procedure. Further, the bonding of the outer layer to the shaft portion is difficult, necessitating the assembling thereof. Accordingly, a compound roll produced by such a method is not suitable for rolling thin plates. And when it is applied to rolls for rolling shaped steel, the number of caliber is restricted. The compound roll of the present invention does not suffer from these problems.

50

Claims

1. A wear-resistant compound roll comprising an outer layer (8) and a shaft portion (10) produced by a centrifugal casting method, said outer layer (8) and said shaft portion (10) being metallurgically bonded to each other, said outer layer (8) being made of an iron-base alloy having a composition (by weight %) consisting essentially of 1-4% of C, 3% or less of Si, 1.5% or less of Mn, 4% or less of Ni, 2-15% of Cr, 8% or less of Mo, 20% or less of W, 2-10% of V and balance substantially Fe and inevitable impurities, the value of C (%) + 0.4 V (%) being 6.0 or less.

2. The wear-resistant compound roll according to claim 1, wherein said iron-base alloy further contains 5 weight % or less of one or more elements selected from Ti, Zr and Nb.
3. The wear-resistant compound roll according to claim 1 or 2, wherein said iron-base alloy further contains 15 weight % or less of Co.
4. The wear-resistant compound roll according to any one of claims 1-3, wherein said shaft portion (10) is made of ductile cast iron.
- 10 5. The wear-resistant compound roll according to any one of claims 1-3, wherein said shaft portion (10) is made of gray cast iron.
6. The wear-resistant compound roll according to any one of claims 1-3, wherein said shaft portion (10) is made of graphitic cast steel.
- 15 7. The wear-resistant compound roll according to any one of claims 1-3, wherein said shaft portion (10) is made of cast steel containing 2.0 weight % or less of C.
8. The wear-resistant compound roll according to any one of claims 1-3, wherein said shaft portion (10) is made of gray cast iron or ductile cast iron, and there is an intermediate layer (9) between said outer layer (8) and said shaft portion (10), said intermediate layer (9) being made of an iron-base alloy containing 2.5 weight % or less of C.

25

30

35

40

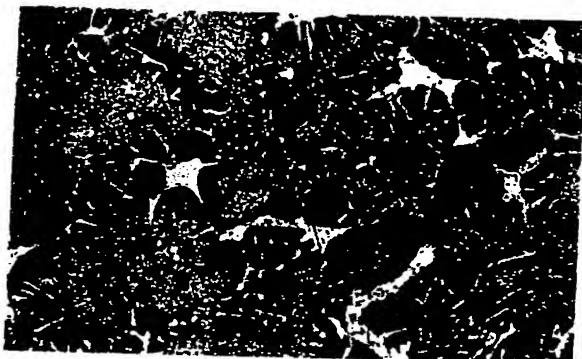
45

50

55

FIG. I

(1)



100 μ m

(2)



1 mm

FIG. 2

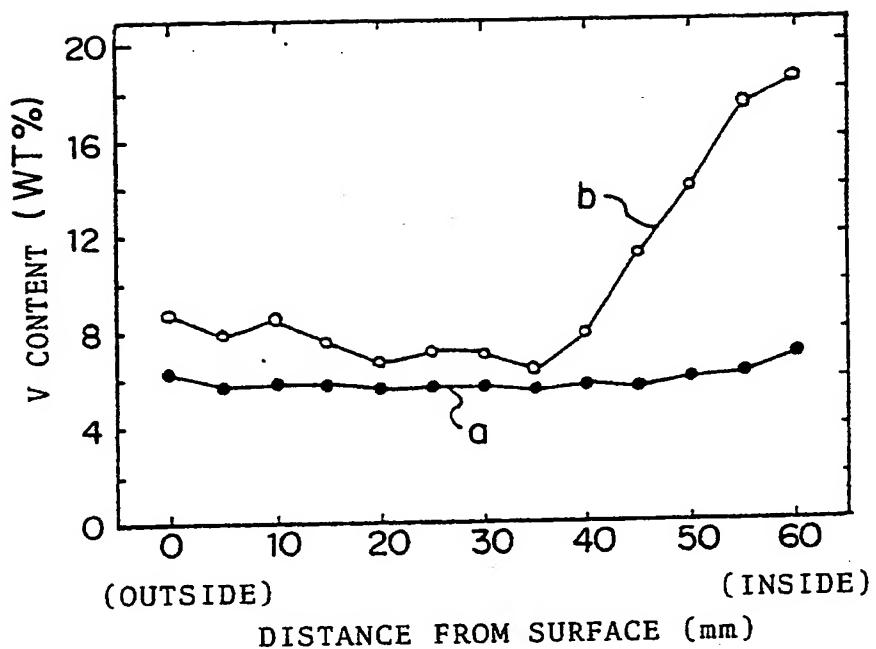


FIG. 3

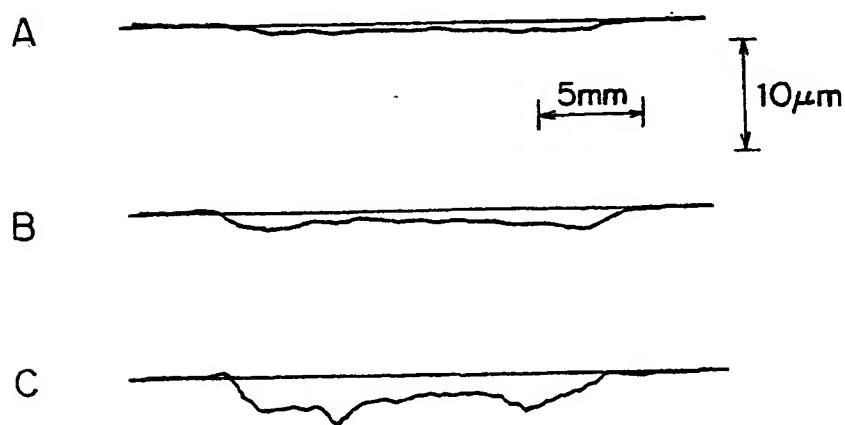
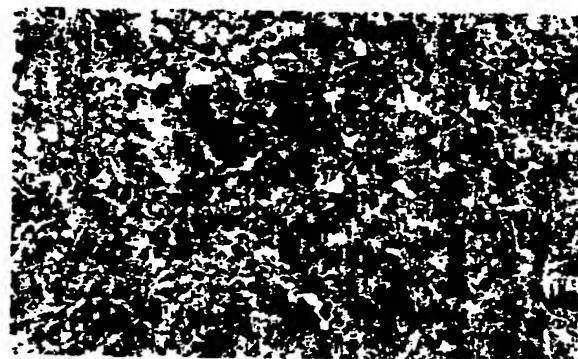


FIG. 4



10 μm

FIG. 5

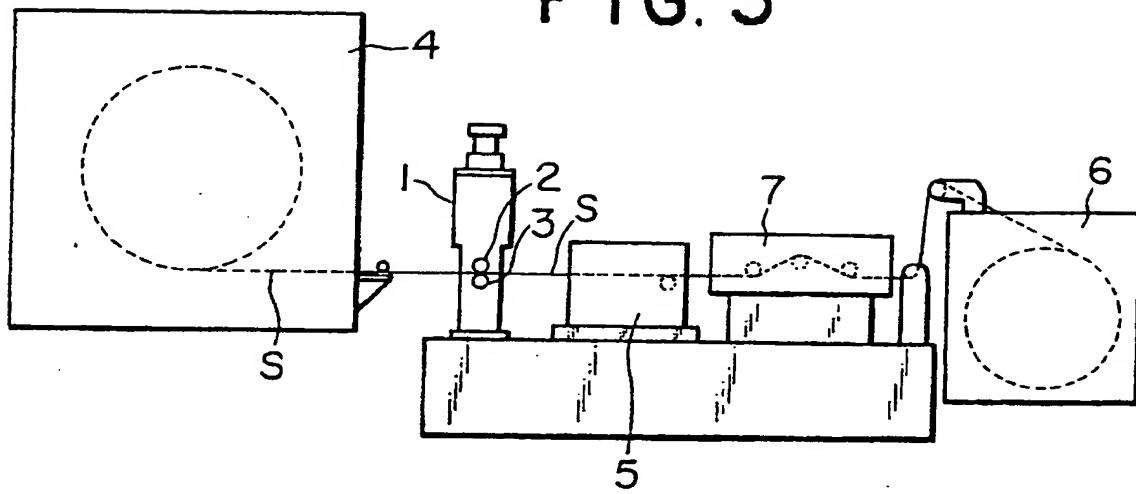
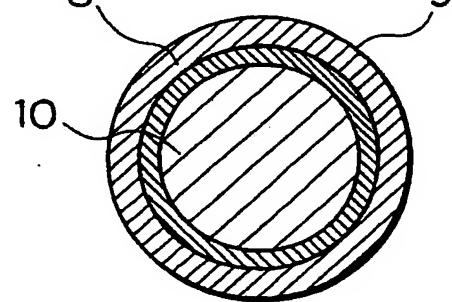


FIG. 6



THIS PAGE BLANK (USPTO)



DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 309 587 (HITACHI METALS) * Claims 1-8; table 1; examples 1-16 * ---	1-3	B 32 B 15/01 C 22 C 37/06
X	EP-A-0 322 315 (CHAVANNE-KETIN and IRSID) * Claims 1,2; page 8, lines 3-11 (example 1); page 10, lines 13-21 (example 2) * ---	1,4	
A	US-A-4 433 032 (NAKAMURA et al.) * Claims 1-6; table; columns 7,8 * & DE-A-3 116 227 (KUBOTA LTD) ---	4,8	
A	DE-A-3 236 268 (HITACHI METALS) * Claims 1,2 * -----	1,3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			B 32 B C 22 C
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	08-03-1991	LIPPENS M.H.	
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone	T : theory or principle underlying the invention		
Y : particularly relevant if combined with another document of the same category	E : earlier patent document, but published on, or after the filing date		
A : technological background	D : document cited in the application		
O : non-written disclosure	L : document cited for other reasons		
P : intermediate document	& : member of the same patent family, corresponding document		

THIS PAGE BLANK (USPTO)